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## PROJECT SUMMARIES

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### PAN ARCHITECTURE FOR DYNAMIC PLANNING SYSTEMS USING LOOSELY COUPLED COMPONENTS

Gordon H. Bradley, Professor

Arnold H. Buss, Visiting Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

**OBJECTIVE:** To design and develop an architecture for dynamic map-based military planning applications using new platform-independent software technology. This is a continuing research project.

**SUMMARY:** The research has designed and developed a “loosely coupled components” architecture that has been demonstrated by constructing a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding additional components.

#### PUBLICATIONS:

Bradley, G. and Buss, A., “Dynamic, Distributed, Platform Independent OR/MS Applications-A Network Perspective,” *INFORMS Journal on Computing*, Vol. 10, No. 4, pp. 384-387, Fall 1998.

Buss, A. and Jackson, L., “Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI,” *Proceedings of the 1998 Winter Simulation Conference*, pp. 819-825, Washington, DC, December 1998.

Buttrey, S. and Bradley, G., “Dynamic, Interactive Statistical Research Papers on the Web,” *Proceedings of the Statistical Computing Section of the American Statistical Association*, pp. 1-6, Anaheim, CA, 1997.

Page, E., Buss, A.P., Fishwick, K., Healy, R., Nance, R., and Paul, R., “The Modeling Methodological Impacts of Web-Based Simulation,” *Proceedings of the 1998 International Conference on Web-Based Modeling and Simulation*, January 1998.

#### CONFERENCE PRESENTATIONS:

Bradley, G., “Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies,” 2<sup>nd</sup> Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., “Map-Based Dynamic Planning Systems in Java,” INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., “Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems,” 66th Military Operations Research Society Symposium, Monterey, CA, 23 -25 June 1998.

Bradley, G., Buss, A., Bilyeu, A., and Arntzen, A., “Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies,” Air Force Office of Scientific Research - New World Vistas Project Review, Monterey, CA, 5 May 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, “Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies,” MPARE IPT Conference, USSOCOM, MacDill AFB, Tampa, FL, 10-14 August 1998.

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Bradley, G., "Tutorial: Java Introduction and OR Applications," 6th INFORMS Computer Science Technical Section Conference on Computer Science and Operations Research: Recent Advances in the Interface, Monterey, CA, 7-9 January 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington DC, 13-16 December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

### THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Bilyeu, Allan L., "Concept for a Special Operations Planning and Analysis System," Master's Thesis, Naval Postgraduate School, June 1998.

Castle, Timothy S., "Coordinated Area Search and Rescue (SAR) Planning and Execution Tool," Master's Thesis, Naval Postgraduate School, September 1998.

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate, June 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

Schwartz, Victor S., "Dynamic Platform-Independent Meta-Algorithms for Graph-Partitioning," Master's Thesis, Naval Postgraduate School, September 1998.

### OTHER:

SOFLCC: A system to support real-time and near real-time decision-making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

**KEYWORDS:** Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

### FUTURE TECHNOLOGIES FOR SPECIAL OPERATIONS MISSION PLANNING, ANALYSIS, REHEARSAL, AND EXECUTION (MPARE)

**Gordon H. Bradley, Professor**

**Arnold H. Buss, Visiting Assistant Professor**

**LTC Charles H. Shaw, III, USA, Military Instructor**

**Department of Operations Research**

**Sponsor: U.S. Special Operations Command**

**OBJECTIVE:** To research and analyze emerging and leap-ahead technologies in support of USSOCOM in the requirements stage for its Mission Planning, Analysis, Rehearsal, and Execution (MPARE) initiative and to advise and support on technology trends and future technology capabilities in C4I.

## PROJECT SUMMARIES

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**SUMMARY:** The research has analyzed the use of platform independent, dynamic, distributed hardware, and software systems to support Special Forces mission planning and execution. Capabilities have been shown with a technology demonstration system for map-based planning. The future technology section of the MPARE CONOPS was developed.

### PUBLICATIONS:

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference*, Washington, DC, pp. 819-825, December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," *Proceedings of the 1998 International Conference on Web-Based Modeling & Simulation*, January 1998.

Shaw, Charles H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," *Proceedings of the 66<sup>th</sup> Military Operations Research Society Symposium*, pp. 159, Monterey, CA, June 1998.

### CONFERENCE PRESENTATIONS:

Bilyeu, A. and Shaw, C.H., III, "Platform Independent, Distributed, Dynamic, Map-Based Military Planning and Analysis Systems for SOF," 66th Military Operations Research Society Symposium, Monterey CA, 23-25 June 1998.

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2<sup>nd</sup> Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, Tampa, FL, 10-14 August 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington, DC, 13-16 December 1998.

Lanquist, T. and Shaw, C.H., III, "Logistics Planning Factors for Special Operations Forces (SOF) Logistics Modeling and Simulation," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Page, E., Buss, A.P., Fishwick, K., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

Shaw, C.H., III, "Map-Based Dynamic Planning and Analysis Using Java and CORBA," Joint Mission Analysis (JMA) and MPARE Integrated Product Team (IPT) Conference, Tampa, FL, 2-6 February 1998.

Shaw, C.H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Modeling Logistics in Full Spectrum Operations/Operations Other Than War (FSO/OOTW)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

## PROJECT SUMMARIES

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### THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate, June 1998.

Lanquist, Timothy S., "Army Special Operations Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Keith E., "Analyzing Sensor-Shooter Links through Simulation," Master's Thesis, Naval Postgraduate School, June 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

Wagner, Brett A., "Air Force Special Operation Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

### OTHER:

SOFLCC: A system to support real-time and near real-time decision-making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

SOFLOGPLNR Software Programs

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

**KEYWORDS:** Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

### **PLATFORM-INDEPENDENT, DISTRIBUTED MAP-BASED DYNAMIC MILITARY PLANNING FOR JOINT SPECIAL FORCES OPERATIONS**

**Gordon H. Bradley, Professor**

**LTC Charles H. Shaw, III, USA, Military Instructor**

**Department of Operations Research**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** Support ongoing research designing and developing an architecture for dynamic map-based planning applications using new platform independent software technology.

**SUMMARY:** The research has analyzed the use of platform independent, dynamic, distributed hardware and software systems to support Special Forces mission planning and execution. The research has designed and developed a technology demonstration system for a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding additional components. In addition, Logistics Planning Factors for SOF unique units and operations were researched and derived for use in support planning.

## PROJECT SUMMARIES

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### PUBLICATION:

Shaw, Charles H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," *Proceedings of the 66<sup>th</sup> Military Operations Research Society Symposium*, pp. 159, Monterey, CA, June 1998.

### CONFERENCE PRESENTATIONS:

Bilyeu, A. and Shaw, C.H., III, "Platform Independent, Distributed, Dynamic, Map-Based Military Planning and Analysis Systems for SOF," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2<sup>nd</sup> Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23 -25 June 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, Tampa, FL, 10-14 August 1998.

Lanquist, T. and Shaw, C.H., III, "Logistics Planning Factors for Special Operations Forces (SOF) Logistics Modeling and Simulation," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Map-Based Dynamic Planning and Analysis Using Java and CORBA," Joint Mission Analysis (JMA) and MPARE Integrated Product Team (IPT) Conference, Tampa, FL, 2-6 February 1998.

Shaw, C.H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Modeling Logistics in Full Spectrum Operations/Operations Other Than War (FSO/OOTW)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

### THESES DIRECTED:

Bilyeu, Allan L., "Concept for a Special Operations Planning and Analysis System," Master's Thesis, Naval Postgraduate School, June 1998.

Castle, Timothy S., "Coordinated Area Search and Rescue (SAR) Planning and Execution Tool," Master's Thesis, Naval Postgraduate School, September 1998.

Lanquist, Timothy S., "Army Special Operations Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Keith E., "Analyzing Sensor-Shooter Links Through Simulation," Master's Thesis, Naval Postgraduate School, June 1998.

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## PROJECT SUMMARIES

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Wagner, Brett A., “Air Force Special Operation Forces Logistics Planning Aid,” Master’s Thesis, Naval Postgraduate School, September 1998.

### OTHER:

Software deliverables to the United States Special Operations Command (USSOCOM) included the Special Operations Forces Logistics Planner (SOFLOGPLNR) programs for each Service component and the Special Operations Forces Loosely Coupled Components Planning and Analysis Program (SOFLCC Program).

SOFLOGPLNR is a set of three software programs to support real-time logistics estimation and support planning for SOF using an MS Windows and Visual Basic Graphical User Interface (GUI) and Logistics Planning Factors specific to SOF in an Excel Spreadsheet.

SOFLCC is a system to support real-time and near real-time decision-making for SOF using network models based on the Loosely Coupled Components Architecture (LCCA).

**DoD KEY TECHNOLOGY AREAS:** Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

**KEYWORDS:** Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

### LARGE-SCALE OPTIMIZATION

**Gordon H. Bradley, Professor**

**Gerald G. Brown, Professor**

**R. Kevin Wood, Professor**

**Department of Operations Research**

**Sponsors: Office of Naval Research and Naval Postgraduate School**

**OBJECTIVE:** To use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and develop graph and network algorithms for dynamic map-based military planning applications. This is a continuing research project.

**SUMMARY:** One part of this research designed and developed a toolkit of methods to quickly construct graph and network algorithms. The algorithms were integrated into a dynamic map-based military planning system that operates over heterogeneous computer networks. The system can download algorithms over a computer network and execute them to analyze operations. The design allows algorithms to be easily added to the planning system. Another part of this research developed new Monte Carlo methods for evaluating the accuracy of solutions to stochastic programming models. We have also developed a new class of simplicial penalties applicable in lieu of polyhedral cuts to encourage admissible integer polyhedral solutions.

### PUBLICATIONS:

Appleget, J. and Wood, K., “Explicit-Constraint Branching for Solving Mixed-Integer Programs,” in review.

Bradley, G. and Buss, A., “Dynamic, Distributed, Platform Independent OR/MS Applications—A Network Perspective,” *INFORMS Journal on Computing*, 10, pp. 384-387, 1998.

Brown, G., Bausch, D., and Ronen, D., “Scheduling Short-Term Marine Transport of Bulk Products,” *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.



## PROJECT SUMMARIES

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Brown, G., Dell, R., and Olson, M., "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," in review.

Cormican, K., Morton, D., and Wood, K., "Stochastic Network Interdiction," *Operations Research*, 46, pp. 184-197, 1998.

Kerman, C.K., Brown, G., and Dell, R., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

Morton, D., Mak, W., and Wood, K., "Monte Carlo Bounding Techniques for Verifying Solution Quality in Stochastic Programs," *OR Letters*, to appear.

Morton, D. and Wood, K., "Restricted-Recourse Bounds for Stochastic Linear Programming," *Operations Research*, to appear.

Morton D. and Wood, K., "A Class of Optimistic Monte Carlo Bounds for Stochastic Programming," in review.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," *Advances in Computational and Stochastic Optimization, Logic Programming, and Heuristic Search: Interfaces in Computer Science and Operations Research*, D.L. Woodruff, (ed.), pp. 149-168, 1998.

Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

## CONFERENCE PRESENTATIONS:

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2<sup>nd</sup> Center of Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

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Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

Israeli, E. and Wood, K., "Maximizing a Shortest Path," INFORMS National Meeting, Seattle, WA, 25-28 October 1998.

## PROJECT SUMMARIES

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Morton, D. and Wood, K., “Optimistic Bounds for Stochastic Optimization,” Prague Stochastics 98, Charles University, Prague, Czech Republic, 23-28 August 1998.

Morton, D. and Wood, K., “Optimistic Monte Carlo Bounds for Stochastic Programming,” VII International Conference on Stochastic Programming, Vancouver, BC, Canada, 8-16 August 1998.

Morton, D. and Wood, K., “On a Stochastic Knapsack Problem and Generalizations,” 6th INFORMS Computer Science Technical Section Conference, Monterey, CA, 6-9 January 1998.

### THESES DIRECTED:

Albright, Michael H., “An Optimization-Based Decision Support Model for the Navy H-60 Helicopter Preventive Maintenance Program,” Master’s Thesis, Naval Postgraduate School, September 1998.

Ayik, Mehmet, “Optimal Long-Term Aircraft Carrier Deployment Planning with Synchronous Depot Level Maintenance Scheduling,” Master’s Thesis, Naval Postgraduate School, March 1998.

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Theres, Michael J., “Models for Comparing Air-Only and Sea/Air Transportation of Wartime Deployment Cargo,” Master’s Thesis, Naval Postgraduate School, September 1998.

Tivnan, Brian F., “Optimizing United States Marine Corps Enlisted Assignments,” Master’s Thesis, Naval Postgraduate School, September 1998.

Viado, Harold A., “An Optimization Model of Class III (Bulk Fuel) Supply for a Deployed MEU (SOC) through Sea-Based Logistics,” Master’s Thesis, Naval Postgraduate School, September 1998.

Yost, Kirk A., “Solution of Large-Scale Allocation Problems with Partially Observable Outcomes,” Dissertation, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

**KEYWORDS:** Integer Programming, Stochastic Programming, Dynamic Planning

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## PROJECT SUMMARIES

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### LARGE-SCALE OPTIMIZATION

Gerald G. Brown, Professor

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

**OBJECTIVE:** Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models. Develop new shortest-path network-interdiction techniques and extensions.

**SUMMARY:** This research developed new Monte Carlo methods for evaluating the accuracy of solutions to stochastic programming models and developed new deterministic bounds for stochastic programs. We have also developed a new class of simplicial penalties applicable in lieu of polyhedral cuts to encourage admissible integer polyhedral solutions. Additionally, we have developed new network-interdiction models and solution techniques that readily generalize to more complicated system models.

### PUBLICATIONS:

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Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.

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Morton, D. and Wood, K., "Restricted-Recourse Bounds for Stochastic Linear Programming," *Operations Research*, to appear.

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Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

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Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

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Ayik, Mehmet, “Optimal Long-Term Aircraft Carrier Deployment Planning with Synchronous Depot Level Maintenance Scheduling,” Master’s Thesis, Naval Postgraduate School, March 1998.

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Yost, Kirk A., “Solution of Large-Scale Allocation Problems with Partially Observable Outcomes,” Dissertation, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Computing and Software, Other (Decision Support Systems)

**KEYWORDS:** Integer Programming, Stochastic Programming

**SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH,  
NATIONAL SECURITY AGENCY  
Gerald G. Brown, Professor  
Department of Operations Research  
Sponsor: National Security Agency**

**OBJECTIVE:** To provide on-call analytical support to the National Security Agency.

**SUMMARY:** Available from sponsor.

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## PROJECT SUMMARIES

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### **PUBLICATION:**

Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

### **CONFERENCE PRESENTATION:**

Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

### **THESES DIRECTED:**

Brandeau, John F., "An Algorithm for Classifying PSTN Switching Stations," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Allen S., "Classifying PSTN Switching Stations: A National Security Agency Application," Master's Thesis, Naval Postgraduate School, September 1998.

Yost, Kirk A., "Solution of Large-Scale Allocation Problems with Partially Observable Outcomes," Dissertation, Naval Postgraduate School, 1998.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

**KEYWORD:** Optimization

**CHAIR OF APPLIED SYSTEMS ANALYSIS**  
**CDR Ronald L. Brown, USN, Military Instructor**  
**Department of Operations Research**  
**Sponsor: Chief of Naval Operations (N81)**

**OBJECTIVE:** To provide a direct relationship between the Director, Assessment Division (N81) and the Superintendent of the Naval Postgraduate School and support activities designated in the joint Memorandum of Understanding between the Superintendent and N81.

**SUMMARY:** During the current year, funding was used for support of student and faculty travel required during thesis and research work, support of faculty course development and research, and support of hardware and software upgrades within the Operations Research Department.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Operations Research, Modeling and Simulation, Curriculum Development

**COMPONENT-BASED SIMULATION METHODOLOGY**  
**Arnold H. Buss, Visiting Assistant Professor**  
**Department of Operations Research**  
**Sponsor: Unfunded**

**OBJECTIVE:** To develop an effective modeling methodology for formulating and analyzing simulation models with superior robustness and timeliness.

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**SUMMARY:** Traditional simulation methodology provides power means to formulate models for situations intractable using any other approach. Unfortunately, simulations models can be extremely costly to implement and equally costly to maintain, debug, and analyze. This work is an ongoing attempt to remedy this situation by developing a component-based simulation approach grounded in sound methodology and implemented in a modern, platform-independent language.

### PUBLICATIONS:

Bradley, G. and Buss, A., "Dynamic, Distributed, Platform Independent OR/MS Applications-A Network Perspective," *INFORMS Journal on Computing*, Vol. 10, No. 4, pp. 384-387, Fall 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference*, Washington, DC, pp. 819-825, December 1998.

### CONFERENCE PRESENTATIONS:

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington, DC, 13-16 December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

### OTHER:

*Simkit*, a Java package for discrete-event simulation modeling.

### THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Computing and Software

**KEYWORDS:** Discrete Event Simulation Methodology, Component-Based Modeling, Modeling and Simulation

### A HIGH LEVEL ARCHITECTURE (HLA) FEDERATE FOR DATA COLLECTION AND ANALYSIS

**Arnold H. Buss, Visiting Assistant Professor  
Department of Operations Research**

**Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey**

**OBJECTIVE:** To develop a prototype of an Analysis Federate for data collection and analysis under the High Level Architecture (HLA).

**SUMMARY:** The High Level Architecture (HLA) is an emerging standard for distributed Modeling and Simulation (M&S). Data collection under HLA can be problematic since the standard does not directly provide logging capabilities. The Analysis Federate will provide near real-time derived data management for federations running simulations under HLA and also allow for collection and exchange of such data after each distributed simulation session. This approach combines the best aspects of data logging and subscription and reduces data logging requirements during the simulation run. Analysis Feder-

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## PROJECT SUMMARIES

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ate services take the form of extensible, reusable objects that collect, process, and display data. The potential benefits of this work are significant since data collection is a universal requirement in simulation sessions. The implementation of future advanced distributed simulations including the CASTFOREM re-implementation, OneSAF, and JWARS will potentially benefit from this project.

### **THESIS DIRECTED:**

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate School, June 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Computing and Software

**KEYWORDS:** Analysis Federate, High Level Architecture (HLA), CASTFOREM Re-implementation, OneSAF, JWARS

### **OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT**

**Robert F. Dell, Associate Professor**

**Department of Operations Research**

**Sponsors: Army Base Realignment and Closure Office and Naval Postgraduate School**

**OBJECTIVE:** To develop optimization models to assist with installation management.

**SUMMARY:** The investigator is providing research, support, and development of optimization models to assist the Army's Base Realignment and Closure Office (BRACO). There are three modeling efforts at different levels of development in 1998: (1) continued refinement to BRACAS (Base Realignment and Closure Action Scheduler), an optimization model developed by the investigator and used extensively by BRACO; (2) initial development of an optimization model to assist with allocation of installation operating budgets; and (3) initial development of an optimization model to assist with allocation of environmental clean-up budgets.

### **PUBLICATIONS:**

Dell, R.F., "Optimizing Army Base Realignment and Closure," *Interfaces*, Vol. 28, No. 6, pp. 1-8, November/December 1998.

Kerman C.K., Brown, G.G., and Dell, R.F., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

### **THESIS DIRECTED:**

Chilson, C., "Minimizing Army Cadet Temporary Duty," Master's Thesis Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREA:** Other (Optimization)

**KEYWORDS:** BRAC, Capital Budgeting, Optimization, Mixed Linear Integer Programming Application

## PROJECT SUMMARIES

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### INVESTIGATION INTO REPRESENTATIONS OF INTELLIGENCE, PERCEPTION AND UNCERTAINTY WITHIN OPERATIONAL DETERMINISTIC SIMULATIONS

**Donald P. Gaver, Distinguished Professor**

**Patricia A. Jacobs, Professor**

**Department of Operations Research**

**Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey**

**OBJECTIVE:** To develop a methodology for an operational perception that quantifies uncertainty and reflects information warfare.

**SUMMARY:** A search of the literature on human factors influencing decision making was conducted.

#### **PUBLICATION:**

Jacobs, P.A. and Gaver, D.P., "Human Factors Influencing Decision Making," Naval Postgraduate School Technical Report, NPS-OR-98-003, July 1998.

**DoD KEY TECHNOLOGY AREA:** Human-System Interface

**KEYWORDS:** Decision Making, Human Factors

### RESEARCH IN JOINT WARFARE MODELING AND SIMULATION EMPHASIZING INFORMATION WARFARE ISSUES

**Donald P. Gaver, Distinguished Professor**

**Patricia A. Jacobs, Professor**

**Department of Operations Research**

**Sponsors: Director, Operational Test and Evaluation, Naval Postgraduate School-Institute for Joint Warfare Analysis, and Strategic Planning Office (N6C3)**

**OBJECTIVE:** The purpose of the research is to formulate and study state-space models for information operations in joint warfare, with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts.

**SUMMARY:** Models for the effect of Battle Damage Assessment (BDA) on targeting have been formulated and studied. The effect of various levels of sensor effort on combat has been and is being modeled in various scenarios. Models to assess the suitability of UAVs have been formulated and studied. Models for suppression of enemy air defense have been formulated and studied.

#### **PUBLICATIONS:**

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Analytical Models for Battlespace Information War (BAT-IW) Part 1," Naval Postgraduate School Technical Report, NPS-OR-98-001, February 1998.

Gaver, D.P. and Jacobs, P.A. "Suppression of Enemy Air Defense (SEAD) as an Information Duel," Naval Postgraduate School Technical Report, NPS-OR-98-005, August 1998.

Gaver, D.P., Jacobs, P.A., and Stoneman, J., "Analytical Models for Mobile Sensor (UAV) Coverage of a Region," Naval Postgraduate School Institute for Joint Warfare Analysis Technical Report, May 1998.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Analytical Models for Battlespace Information War (BAT-IW) Part 2," forthcoming.



## PROJECT SUMMARIES

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Gaver, D.P., Jacobs, P.A., and Youngren, M.A., “Binomial-like Sensors,” in progress.

Gaver, D.P., Jacobs, P.A., Youngren, M.A., and Parry, S.H., “Models for Force Interaction that Involve Uncertain Perception,” forthcoming.

Davis, D.S., “Basic Physics of Target Sensing for Joint Theater-Level Models of the Future,” forthcoming.

Gaver, D.P. and Jacobs, P.A., “In Search of Military Unit Formations: G-String Models,” forthcoming.

Gaver, D.P. and Jacobs, P.A., “A Model for Analyzing Blue Force Response to Region Invasion by Multi-Type Red Forces,” forthcoming.

Gaver, D.P. and Jacobs, P.A., “Models for the Outcomes of Uncertain Task Service with Deadlines,” forthcoming.

Glazebrook, K.D., “On a Military Scheduling Problem,” forthcoming.

### CONFERENCE PRESENTATION:

Gaver, D.P. and Jacobs, P.A., “Controlling Service When Service Completion is Uncertain,” INFORMS National Meeting, Montreal, Canada, 26-29 April 1998.

### OTHER:

Bullock, G., Delphi software implementation of models for Blue force response to region invasion by multi-type Red forces, December 1998.

### THESES DIRECTED

Haugen, N., “An Analysis of a Delay in the Intelligence Cycle and Its Effect on a Suppression of Enemy Air Defense (SEAD) Operation,” Master’s Thesis, Naval Postgraduate School, September 1998.

Hencke, R.B., “An Agent-Based Approach to Analyzing Information and Coordination in Combat,” Master’s Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Human-System Interface, Modeling and Simulation

**KEYWORDS:** Combat Models, Bayesian Perception Updating, Decision Analysis

### THE NAVAL SIMULATION SYSTEM (NSS) MODEL STUDY

**Donald P. Gaver, Distinguished Professor**

**Patricia A. Jacobs, Professor**

**Department of Operations Research**

**Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey**

**OBJECTIVE:** To provide independent reviews of the simulation model NSS to the NSS Government Program Office.

**SUMMARY:** Reviews of the Joint Forces Air Component Command (JFACC) support graphical user interface and the theater missile defense (TMD) graphical user interface were conducted. Documents describing the results of the review of the JFACC support graphical user interface and the theater missile defense graphical user interface have been delivered to the sponsor.

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## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREA:** Human-System Interface

**KEYWORDS:** Graphical User Interface, Strike Warfare

**TRAINING AND RESEARCH SUPPORT FOR DIRECTOR,  
OPERATIONAL TEST AND EVALUATION**  
**Donald P. Gaver, Distinguished Professor**  
**Patricia A. Jacobs, Professor**  
**Department of Operations Research**  
**Sponsor: Commander, Operational Test and Evaluation Force**

**OBJECTIVE:** Purpose of the research is to develop training and reference material on a web site and new methodology for operational testing use emphasizing modeling and simulation.

**SUMMARY:** Models to assess the operational suitability of UAVs have been formulated and studied. Materials for an operational test and evaluation web site have been developed. Spreadsheet implementations of the bootstrap for analysis of failure data were developed as well as a spreadsheet implementation of UAV model calculations.

### **PUBLICATIONS:**

Gaver, D.P. and Jacobs, P.A., "Assessing and Controlling the Availability of Failure-Degraded Service Agents," Naval Postgraduate School Technical Report, NPS-OR-98-002, May 1998.

Gaver, D.P., Jacobs, P.A., and Dudenhoefter, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," *Applied Stochastic Models and Data Analysis*, 13, pp. 369-376, 1998.

Gaver, D.P. and Jacobs, P.A., "Methodology for an Operationally-Based Test Length Decision." *IIE Transactions* Vol. 30, 1998, to appear.

### **CONFERENCE PRESENTATIONS:**

Gaver, D.P. and Jacobs, P.A., "Reliability Issues in Testing and Operations," Lucent Technologies, Holmdel, NJ, 9 July 1998.

Gaver, D.P., Jacobs, P.A., and Stoneman, J.G., "Modeling of UAV Sustainability for Regional Surveillance," NPS-NRL Meeting on UAVs, 26 October 1998.

### **THESES DIRECTED:**

Stoneman, J.S., "Operational Analysis of the Sustainability of a Mobile Military Platform," Master's Thesis, Naval Postgraduate School, September 1998.

Werenskjold, George K. "An Exploratory Analysis of Corrective Maintenance During Extended Surface Ship Deployment," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREAS:** Human-System Interface, Modeling and Simulation

**KEYWORDS:** Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

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## PROJECT SUMMARIES

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### FORECASTING THE RETENTION OF NAVAL AVIATORS

**William K. Krebs, Assistant Professor**  
**Samuel E. Buttrey, Assistant Professor**  
**Department of Operations Research**  
**Sponsor: Naval Air Systems Command**

**OBJECTIVE:** Navy, Marine, and Air Force senior leadership has stated that at the current rate of pilot resignation and that given the paucity of aviators accepting the bonus, operational readiness can be expected to decrease. The objective of this study was twofold. First, a questionnaire was developed to examine the quality-of-life issues that were important to the retention decisions of aviators. Second a statistical model was developed that predicts retention based on attributes of the aviators recorded in the Officer Master File.

**SUMMARY:** Approximately 1700 Navy and Marine Corps aviators were surveyed to measure their attitudes on retention. Previous research has indicated that measurements of job satisfaction are the most reliable predictor of one's intent to remain with an existing employer. The results showed that most aviators today are positively motivated by high-level needs such as affiliation (Co-worker Satisfaction) and job fulfillment (Work Satisfaction). Pay Satisfaction factors were considerably more significant for senior, than for junior, aviators as predictors of intent to remain in the service. Retirement pay concerns lent much greater impact to predicted behavior than special pay (ACP/ACIP) considerations did.

Current models of aviator retention incorporate external economic factors like civil aviation hiring. They do not take into account demographic and professional attributes of the aviators themselves, like family status, months of operational flying, and commissioning source. A statistical model was developed that used the Officer Master File (OMF) fiscal year 1995 demographic and professional aviator attributes to predict the retention behavior of the OMF fiscal year 1996 aviators. The statistical model, a classification tree, divided the aviators into a series of nodes based on a binomial distribution. At the top of the tree diagram, the first node specified that 8.7% of the 4400 aviators left military service after fiscal year 1995. The aviators who stayed in military service were then split into two separate nodes with each path categorized by commissioning source. The results showed that ROTC and Academy graduates were less likely to leave military service than those with OCS and other types of commissions. The model then further split each commission node into two more nodes that were based on a different attribute. The model continued to subdivide each node until the data better explained but not overfit. The fiscal year 1995 and 1996 node classifications were then compared to determine whether the model could accurately predict what classes of aviators were most likely to leave military service. The predictions were fairly accurate; however the model has some shortcomings. In particular some divisions were said to be difficult to interpret. (For example, at one "branch" the tree might separate O-4s from O-3s and O-5s, although intuition would suggest that these two latter groups ought not to be similar.)

While the divisions are "correct" by the algorithm's success criterion, interpretability of the model is also a vital goal. The new model will validate the tree approach with new data as well as ensuring that all of the divisions are interpretable and "user-friendly." N1 will be able to require or prohibit specific divisions to increase the model's interpretability.

### THESES DIRECTED:

Poindexter, S., "Analysis of Mid-Grade Naval Aviator Retention," Master's Thesis, Naval Postgraduate School, September 1998.

Sullivan, D., "Job Satisfaction Among United States Navy and Marine Corps' Aviation Officers - A Study of the Impact on Career Retention," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Aviators, Retention, Force Forecasting

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## PROJECT SUMMARIES

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### PERCEPTUAL PLASTICITY IN A VIRTUAL ENVIRONMENT

**William K. Krebs, Assistant Professor**

**Department of Operations Research**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** To investigate low-level perceptual-adaptation (simulator sickness) effects caused by long-term exposure to a virtual environment (VE). The cause of simulator sickness is unknown, but researchers hypothesize that it's the result of a sensory input mismatch between the visual and vestibular sensory organs. Previous simulator sickness studies used questionnaires to measure sickness severity, however this is a crude measure with inconsistent findings. To further understand the causes of simulator sickness, this study will quantify whether low-level sensory functions are disrupted when erroneous information is presented to the brain, and determine whether long-term simulator exposure causes sensory adaptation. The results of this study may identify simulator sickness symptoms, which should help mission planners optimize the length that aircrew are exposed to a virtual training.

**SUMMARY:** It was hypothesized that a virtual environment simulator will cause an operator's visual system to adapt and then reorganize to match the modified synthetic environment. Forty subjects were randomly assigned to one of four display formats, no exposure (control condition), CRT (29 deg FOV), three-panel display (132 deg FOV), and a HMD (Virtual Research VR8 helmet with a 60 deg FOV). The three-panel and HMD groups were immersed within a driving simulation model, while the CRT group played a video game. A battery of tests (motion sickness questionnaire MSQ, depth perception, smooth pursuit (5,10,20,30, and 36 deg/sec), and Optokinetic Nystagmus (5, 12, 18, and 25 deg/sec sinusoidal grating on the VR8 display)) were administered before and after a 25 minute treatment exposure. Subjects within the HMD showed the highest MSQ scores followed by the three-panel, CRT, and control subjects. Depth perception showed no significant difference between display formats. There was a significant difference between the three-panel and HMD groups compared to the CRT and control groups for the smooth pursuit task for subjects whom reported a history of motion sickness. This suggests that immersion may have reorganized the visual system to adapt to the virtual interface. The results of this study may provide a metric to predict initial onset of post-exposure performance degradation as well as establish standards that specify how many hours an observer may be susceptible to VE adaptation effects.

In addition to the investigation of low-level perceptual effects due to prolonged VE exposure is the study of higher order cognitive functions that interpret a VE scene. Studies on distance perception in the real world found that subjects use texture, size, and shading to estimate an object's distance. Witmer and Kline (1998) reported that subjects' distance perception within a virtual environment was not influenced by texture. This result is surprising due to the number of studies showing that texture has a significant role in distance estimation. The current study will measure the influence of texture on distance perception in a VE using a perceptual-matching task. To test this hypothesis, subjects will estimate the distance of a target displayed through a head-mounted display. Three targets of varying size will be viewed at four distances within a virtual hallway. The hallway texture will consist of three different density patterns—none, medium, and high. Subjects' task will be to estimate the distance of a briefly displayed target viewed in one hallway, turn their head 90° to view a different hallway, then physically match the distance of the previously seen target by moving a similar target along the current hallway. It is hypothesized that texture will influence distance estimation in a virtual environment, which will support previously published literature and discount Witmer and Kline's findings.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Biomedical, Modeling and Simulation

**KEYWORDS:** Virtual Environment, Simulator Sickness, Adaptation

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## PROJECT SUMMARIES

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### BEYOND THIRD GENERATION: ASSESSMENT OF SENSOR FUSION FOR N88'S F/A-18 TARGETING REQUIREMENTS

William K. Krebs, Assistant Professor

Department of Operations Research

Sponsors: Office of Naval Research, Defense Advanced Research Projects Agency, and Lockheed Martin Electronics and Missiles Corporation

**OBJECTIVE:** The Navy and Marine Corps F/A-18 pilots state that the targeting FLIR system does not provide enough target definition and clarity. As a result, high altitude tactics missions are the most difficult due to the limited amount of time available to identify the target. If the targeting FLIR system had a better stand-off range and an improved target contrast then the pilots' task would be easier. Unfortunately, the replacement cost of the existing FLIR equipment is prohibitive. The purpose of this study is to modify the existing F/A-18 targeting FLIR system with a dual-band color sensor to improve target contrast and stand-off ranges.

**SUMMARY:** The Naval Postgraduate School and Naval Research Laboratory have collected simultaneous day and night-time imagery and simulated dual-band sensor fusion systems from a variety of electro-optic sensors. The basic concept of image sensor color fusion is that displaying a color fused image tends to make targets pop-out of the background as compared to a single band monochrome display. A color image emphasizes the background context and allows the user to efficiently search for a target. This in turn should improve operators' situational awareness and target recognition. For example, if color helps the operator discriminate between man-made and natural objects, then the operator will be able to identify the target quicker compared to single band monochrome systems. Flight, ground, and driving single- and dual-band data were collected to demonstrate the potential benefits of image sensor color fusion.

#### Flight Demonstration

A multi-color night vision system on NASA's F/A-18 Day/Night Infrared Imaging/Tracking Laser Target Designating/Ranging System (NITE Hawk) targeting FLIR pod was demonstrated. The aircraft pod was configured with a 1<sup>st</sup> generation scanning FLIR and a color CCD. Three flights recorded video sequences of air-to-ground targets (e.g., tanks, boats) over the restricted area near Naval Air Warfare Center (NAWC) China Lake. Each sequence began with a target beyond visual range, and continued with the target within the sensor's FOV until target overfly (that is, until the target was at a range of 0 nautical miles). Subjects' task was to view the video sequences (infrared, visible, and fused color) and detect a specified target, and to announce "pickle" when the designated target had been acquired. We found that color fusion did not improve pilot's situational awareness. Pilots overwhelmingly reported that the color fused scene appeared unnatural due to the choice of colors and the problems of scene registration. The fused sequences were not able to spatially match every frame thus objects appeared distorted. However, pilots did report that color fused objects were easier to discriminate than infrared or visible objects. Therefore, color fusion may be more appropriate for targeting applications compared to navigation and pilotage applications.

#### Field Data Collection

Ground-based data collection was conducted on April 14<sup>th</sup> and 15<sup>th</sup>, 1998 at Fort A.P. Hill, Virginia to gather data for sensor fusion development. This data collection was the second in a series, which started in the fall of 1997 and will continue through 1998. The Fort A.P. Hill data collection used four different spectral sensors boresighted within a vertical integrated sensor mount. The test consisted of a Lockheed Martin IR & Imaging Systems (LMIRIS) uncooled long-wave infrared sensor, Amber Radiance mid-wave infrared camera, Lockheed Martin (LM) Fairchild low-light camera, and a Pulnix TM-540 visible near infrared camera. The test methodology consisted of five different scenarios that varied across terrain (open field to dense forest) by target types (M2 Bradely, M60, M113 APC, M35 2.5 ton truck, and a HMMWV). Each data collection session lasted approximately eight hours with four scenarios tested each session. The majority of data was collected during full moon illumination with a couple of hours during sunrise. Meteorological and GPS data on selected targets were collected during both sessions. Within each session, analog video was continually recorded for each sensor and selected digital segments were recorded using a specially configured portable digital collection workstation. Digital sequences were limited to three minutes, thereby allowing time to archive the digital files.

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## PROJECT SUMMARIES

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Digital and analog data was used to evaluate the information conveyed by single- and dual-band sensor imagery by assessing operator performance on a scene recognition task. Subjects viewed a 100-msec image followed by a 300-msec checkerboard mask. A second image, of the same or of a different sensor format, was then displayed and remained visible until a response was made. The observer's task was to indicate whether the first and second image depicted the same scene, regardless of which sensor format the scenes were displayed in. Performance was best when the first and second images were presented in the same format. When format changed between the presentation of the two images, performance deteriorated, but more so when the second image was of a single band format. Format of the first image itself had little effect, indicating that the primary benefits of sensor fusion were in matching the content of the second image to a stored representation of the first, and not in processing the briefly viewed first image. These results suggest that fusion can allow information from multiple single-band sensors to be effectively combined and presented within a single image, within which single-band information remains perceptually accessible.

### Driving Demonstration

Infrared and image-intensified videotaped footage was collected from sensors mounted to the roof of a moving sport utility vehicle, and psychophysical tests have begun to examine how these different sensor types support various perceptual abilities integral to safe night driving—the ability to detect obstructions, the ability to see through the glare of oncoming headlights, the ability to estimate the time until an approaching vehicle passes. An initial study has examined observers' ability to detect a pedestrian against the glare of an approaching car's headlights. Images for this experiment were collected with the sensors facing down a stretch of straight road, and into the headlights of a parked car. Later, in the lab, observers were asked to view these images and to determine whether a pedestrian was visible in each one. Response times for detecting pedestrians were faster in infrared than in image-intensified imagery. More notably, observers' performance using image-intensified imagery declined substantially as targets were located at greater distances from the sensor, and as targets were located nearer the oncoming vehicle's headlights, while performance with infrared imagery showed little effect of target distance or of interference from glare. This suggests that infrared sensors might be effective night driving aids, and could be especially helpful in overcoming difficulties imposed by glare.

### Task Analysis and Predictive Model

A task analysis was conducted to determine what measures are needed to assess the benefits of sensor fusion for military applications. This task analysis consisted of an extensive framework for evaluating sensors, algorithms and operator performance across different but relevant combinations of spectral wavebands. The results of the task analysis were then used to develop quantifiable performance-based metrics to be used in evaluating fused imagery systems requirements and performance.

The second objective was to modify existing analytical operations-research-type models to fit meaningful performance metrics that could be revised and extended where necessary to represent the data obtained during field tests. These modified models may be used to evaluate fused imagery systems requirements and performance. Furthermore, these models may indicate what type of data would be needed to collect in the future.

### THESES DIRECTED:

Bryant, E., "A Process Simulation Design to Assess Promising Technologies Relevant to F/A-18 Aircrew Target Recognition," Master's Thesis, Naval Postgraduate School, September 1998.

White, B., "Evaluation of the Impact of Multispectral Image Fusion on Human Performance in Global Scene Processing," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREAS:** Human Systems Interface, Modeling and Simulation, Air Vehicles, Sensors, Ground Vehicles

**KEYWORDS:** Sensor Fusion, Multi-Spectral, Human Performance, Target Recognition, Driving Aids, Enhanced Vision

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## PROJECT SUMMARIES

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### MODELING ATTRITION OF FIRST-TERM ARMY ENLISTED PERSONNEL

Harold J. Larson, Professor

Samuel E. Buttrey, Assistant Professor

Department of Operations Research

Sponsor: Office of the Deputy Chief of Staff, Personnel (ODCSPER), U.S. Army

**OBJECTIVE:** The Army is updating its military strength management system. That system is used for modeling near-term needs for, and adjustments to, manpower levels, as well as for longer term projections. One portion, the Enlisted Loss Inventory Model (ELIM), projects losses of first-term enlisted personnel. The model bases its projections on characteristic groups (c-groups), whose structure has remained unchanged since the strength management system was initially implemented. These c-groups partition first-term enlisted personnel according to sex, education level, mental category (AFQT group) and term of service in a specific way. It is presumed that members of different c-groups will have different propensities toward attrition. In recent years, however, forecasts made by the ELIM model have not been satisfactory.

This study used Classification and Regression Tree methodology (CART) to generate c-groups for use with ODCSPER's new Military Strength Management System; these new c-groups are designed to differ in first-term retention rates, to the maximum extent possible. As this project continued, interest was also expressed in categorizing differences in retention in the early months of a recruit's first term. In addition, interest arose in groupings which distinguished three groups: those who did not complete the first term, those who did complete the first term but did not re-enlist, and those who did choose to re-enlist at the completion of the first term. CART has also been used for these efforts.

**SUMMARY:** This project was completed at the end of calendar year 1998, and the final report has been delivered to the sponsor. The CART methodology has been useful in defining new c-groups in which attrition rates varied somewhat more than the old. Misclassification rates are also reduced; the improvement is small in percentage terms but reasonably large in terms of the increased number of correct predictions. The technique also demonstrated that attrition rates peak in the early months and reach a steady-state by about month nine; that race and sex are important factors in producing groups with different attrition rates, and that both the peak and steady-state rates are highest for white females and lowest for non-white males. This is partly, but not entirely, because females, especially white females, tend to sign up for the longest terms. The best groups for predicting re-enlistment differ somewhat from those that are best for predicting completion. Finally, the college bonus programs do play a role in re-enlistment, as suspected, but not in term completion.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** CART, Retention, Force Forecasting

### ADDRESSING UNCERTAINTIES AND RANDOMNESS IN DECISION MAKING

Tom Lucas, Associate Professor

Department of Operations Research

Sponsor: Naval Postgraduate School

**OBJECTIVE:** To develop methods that assist decision makers make and justify decisions in an uncertain environment with a dearth of data. This will be addressed in two ways. First, by facilitating the use of Bayesian methods by identifying robust approaches to explicitly combine expert's subjective assessments with (scarce) data. Second, develop approaches to better address uncertainty in (combat) simulations.

**SUMMARY:** Towards the goal of enhancing the ability to quantify prior beliefs, through extensive numerical computations: (1) a (first-cut) list of asymptotic behaviors were developed for a variety of prior functional forms when the data conflicts with how prior beliefs are modeled and (2) how some oft-used models behave were determined with respect to extreme data. It turns out that some of the more popular models make non-robust (implicit) assumptions that seem unreasonable.

To help advance the debate on whether combat simulations should (generally) be deterministic or stochastic: (1) a list of arguments were assembled (both theoretical and practical) for and against deterministic approximations to inherently

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stochastic phenomenon in combat models and (2) a diverse set of examples were gathered where the deterministic approximations severely bias simulation outputs.

### PUBLICATIONS:

Lucas, T., Bennett, B., Friel, J., and Kerchner, R., “ADS for Analysis: Much Agreement, Important Differences,” *PHALANX*, December 1998.

Lucas, T., “Why Most Combat Models Should be Stochastic: Tales of When the Average Won’t Do,” in final preparation.

Lucas, T., “The Warfighting Experiment Analytical Process—Where Do We Go From Here?” in final preparation.

### CONFERENCE PRESENTATIONS:

Lucas, T., “The Warfighting Experiment Analytical Process—Where Do We Go From Here?” U.S. Army Conference on Applied Statistics (ACAS), Las Cruces, NM, October 1998.

Lucas, T., “Improving the Analytical Contribution of Advanced Warfighting Experiments,” 2<sup>nd</sup> Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, July 1998.

### OPTIMIZING INTERMODAL RAIL OPERATIONS

Alexandra M. Newman, Research Assistant Professor

Department of Operations Research

Candace A. Yano, Professor and Chair

Industrial Engineering and Operations Research Department

University of California, Berkeley

Sponsor: Unfunded

**OBJECTIVE:** To develop new techniques for solving large integer programming models with an application in the rail industry for minimizing operational costs of intermodal train scheduling and container routing.

**SUMMARY:** The problem was addressed of how to schedule direct and indirect (via a hub) trains and which containers to send on each train for the rail (linehaul) portion of the intermodal trip. The goal is to minimize operational costs, including a fixed charge for each train, variable transportation and handling costs for each container and yard storage costs, while meeting on-time delivery requirements. The problem was formulated as an integer program and develop a novel decomposition procedure to find near-optimal solutions. A method was also developed to provide relatively tight bounds on our solution values. Finally, the solutions were compared against those obtained with heuristics designed to mimic current operations, and show that a substantial savings can be gained from using the solution procedure.

### PUBLICATION:

Newman, Alexandra M. and Yano, Candace A., “Optimizing Intermodal Rail Operations,” *Proceedings of the 1998 Manufacturing and Service Operations Management Conference*, Seattle, WA, 29-30 June 1998.

### CONFERENCE PRESENTATIONS:

Newman, Alexandra M. and Yano, Candace A., “Optimizing Intermodal Operations over the Rail (Linehaul) Segment of Truck-Rail Intermodal Transportation,” Institute for Operations Research and the Management Sciences Conference, Montreal, Quebec, 26-29 April 1998.

## PROJECT SUMMARIES

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Newman, Alexandra M. and Yano, Candace A., “Optimizing Intermodal Rail Operations,” Manufacturing and Service Operations Management Conference, Seattle, WA, 29-30 June 1998.

Newman, Alexandra M. and Yano, Candace A. “Optimizing Intermodal Rail Operations,” Institute for Operations Research and the Management Sciences Conference, Seattle, WA, 25-28 October 1998.

### **OPERATIONS RESEARCH MODELING FOR OSD (PA&E)**

**Richard E. Rosenthal, Professor**

**Arnold H. Buss, Visiting Assistant Professor**

**Department of Operations Research**

**Sponsor: Office of Secretary of Defense, Program Analysis and Evaluation**

**OBJECTIVE:** To enable Operations Research masters students at the Naval Postgraduate School to take field trips in connection with thesis research on topics of interest to OSD (PA&E), such as understanding of focused logistics.

**SUMMARY:** This project supported LCDR John Ruck’s thesis research on focused logistics, conducted at the request of Mr. James Johnson of OSD (PA&E). The principal accomplishment was the development of the Flexible Experimental Logistics Simulator (FLEXLOGS), whose purpose is the inclusion of logistics-based constraints and considerations in combat models. FLEXLOGS is an object-oriented, discrete-event simulation that can be used to evaluate proposed logistics strategies. The model was used to explore the probability of combat victory vs. “logistical footprint size” and “premium transportation availability.”

#### **THESIS DIRECTED:**

Ruck, John L., “An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics),” Master’s Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Focused Logistics, Object-Oriented Modeling and Simulation

### **ADVANCED TOMAHAWK WEAPONS CONTROL SYSTEM PREDESIGNATION**

**Alexandra M. Newman, Research Assistant Professor**

**Richard E. Rosenthal, Professor**

**Department of Operations Research**

**Sponsors: Naval Surface Warfare Center-Dahlgren Division  
and Office of Naval Research**

**OBJECTIVE:** To improve modeling efforts to aid in the selection and firing of Tomahawk missiles from surface ships and submarines (ongoing).

**SUMMARY:** Tomahawk Land Attack Missile allocation for tasking requirements has traditionally been done manually. Automatic selection of these missiles would improve accuracy and consistency in selection, preserve residual firing capabilities, decrease unnecessary missile expenditure and save valuable time for the strike control officer. This project developed a new optimizing approach to missile-to-mission matching, using integer programming. In a matter of seconds for a single ship or a matter of minutes for a battle group, the optimization model determines which missile to select for each tasking order and provides back-up assignments if requested. The objective of this first model is to ensure the best weapon is applied against each target while maximizing the salvo capability of the firing units to perform future taskings. This accounting of future taskings is indirect; therefore, ongoing research aims to develop a dynamic version of the model that considers tasking orders over multiple time periods. Other enhancements in the second model will be to take into account

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## PROJECT SUMMARIES

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the initial geographic location of ships, preferences as to how missile firings are allocated to ships, and the relative importance of various taskings. A separate, but related, model will be developed for TLAM allocation on submarines.

### **THESIS DIRECTED:**

Kuykendall, S.D., "Optimizing Selection of Tomahawk Cruise Missiles," Master's Thesis, Naval Postgraduate School, March 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Surface/Under Surface Vehicles – Ships and Watercraft

**KEYWORDS:** Missiles, Missile Selection, Naval Operations, Tomahawk Land Attack Missile

### **PLANNING PROCUREMENT AND DEPLOYMENT OF SPACE AND MISSILE ASSETS**

**Alexandra M. Newman, Research Assistant Professor**

**Gerald G. Brown, Professor**

**Robert F. Dell, Associate Professor**

**Richard E. Rosenthal, Professor**

**Department of Operations Research**

**Sponsor: U. S. Air Force Space Command**

**OBJECTIVE:** To improve modeling efforts to aid in the procurement of space-based systems over a 25-year time horizon (ongoing).

**SUMMARY:** The Space Command Optimizer of Utility Toolkit (SCOUT) is a linear integer model developed for the Air Force Space Command to help plan the research and development of space-based systems over a 25-year horizon. SCOUT recommends a mix of concepts, current systems, and launches that minimizes shortfalls in task performance, while adhering to constraints on budget, launcher demand, launcher availability, and logic governing the precedence and interdependence of systems. The current research goal is to improve SCOUT's value to the Air Force Space Command by enhancing model realism and by decreasing the computer time necessary to complete a model run.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Space Vehicles

**KEYWORDS:** Budgeting, Capital Budgeting, Space Systems

### **CONFIGURATION MODELING FOR THE RELIABILITY OF SHORT TAKE-OFF AND LANDING AIRCRAFT**

**Robert R. Read, Professor**

**Department of Operations Research**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** To contribute to the understanding of the effect of the proposed configurations on the reliability and maintainability of several notional Joint Strike Fighter aircraft, one of conventional take-off and landing type, and two of the short take-off and vertical landing type.

**SUMMARY:** Reliability and maintainability studies were made of three designs proposed for the Joint Strike Fighter (JSF): (1) the conventional take-off and landing carrier based aircraft (CV/CTOL); (2) the short take-off and vertical landing (STOVL) of the direct lift type; and (3) STOVL of the lift fan type. The studies took two main forms: (1) a literature search into the characteristics and complexities of the several types and (2) a modeling of the structural components affected by the advanced designs in terms of the failure histories of existing components that play similar roles in operational

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## PROJECT SUMMARIES

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aircraft. Such modeling allows the program managers to anticipate the extent of engineering improvements necessary in order to make the proposed aircraft designs viable and competitive. Several complexity comparisons were made. Reliability computations were made both for the attrition phase and the mission capability aspects for all three designs. Comparisons were made with like computations for the Harrier and Hornet aircraft.

### **PUBLICATION:**

Read, R.R., "Summary of the Reliability and Maintainability Research Relating to the Joint Strike Fighter Program," Naval Postgraduate School Technical Report, NPS-OR-98-007, October 1998.

### **THESIS DIRECTED:**

Boyles, D.E., "A Reliability and Availability Analysis of Notional Joint Strike Fighter Aircraft Designs," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Air Vehicles

**KEYWORDS:** Reliability, Maintainability, Joint Strike Fighter, CV/CTOL, STOVL

### **ESTIMATING THE MEAN WHEN SAMPLING PROVIDES PROBABILITIES AS WELL AS VALUES**

**Robert R. Read, Professor**  
**Alan Washburn, Professor**  
**Department of Operations Research**  
**Lyn Thomas, Professor**  
**University of Edinburgh**  
**Sponsor: Unfunded**

**OBJECTIVE:** To develop schemes for leveraging the extra information provided when the value probabilities are included as output along with the measured values. The goal of sampling is to estimate a population mean. It should be possible to improve upon the arithmetic average of the values under these circumstances.

**SUMMARY:** This is a continuing project. Previous work has produced some criteria for judging good estimates and four techniques for using the extra information to advantage. Some performance comparisons have been generated using Monte Carlo simulation. The work of the current year has resulted in the detailing of some new problems to which our structure applies, and the enhancement of one of our estimators by the development of a confidence interval technique for it.

**DoD KEY TECHNOLOGY AREA:** Other (Mathematical Models)

**KEYWORDS:** Probability, Monte Carlo Simulation

### **COSTS IN THE FUTURE OF NAVAL AVIATION**

**Robert R. Read, Professor**  
**Department of Operations Research**  
**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** To create a spreadsheet cost model that allows "what if" studies to be conducted for a variety of notional configurations of Naval aviation for the period 2000 to 2020.

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**SUMMARY:** This work is in support of a much larger project, “Innovation in Naval Warfare Systems,” under the direction of Professor Mike Melich of NPS’ Institute for Joint Warfare Analysis in which operational capability and combat system procurement issues play central roles. The notional plans for Naval aviation for the period 2000 to 2020 have been acquired including the aircraft carrier build and retirement programs, mix of aircraft types, weapons and personnel requirements. Cost categories have been identified.

**PUBLICATIONS:**

Read, R.R., “Errors of the First and Second Kinds,” *Encyclopedia of Industrial Engineering*, A. Mital, (ed.), 1998.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORD:** Naval Aviation

### OPTIMIZATION MODELING FOR AIRLIFT MOBILITY

**Richard E. Rosenthal, Professor**

**Laura M. Williams, Research Assistant Professor**

**Department of Operations Research**

**Sponsor: U.S. Air Force Studies and Analysis Agency**

**OBJECTIVE:** To provide research and support for the Air Force air mobility modeling effort by enhancing the Naval Postgraduate School/RAND Mobility Optimizer (NRMO) model and supporting studies performed with the model.

**SUMMARY:** Tutorials on the NRMO model were given to both AFSAA and RAND personnel. Support for the OSD(PA&E) Fuels Infrastructure Study being done at RAND was given. This support included creating scenarios, making model runs, performing analysis of model results, and making model enhancements. Enhancements made to the model included: data support for the aerial refueling function, cargo load factors, home station servicing, and fractional flows.

**PUBLICATION:**

Baker, S.F. and Rosenthal, R.E., “A Cascade Approach for Staircase Linear Programs,” Naval Postgraduate School Technical Report, NPS-OR-98-004, July 1998.

**CONFERENCE PRESENTATION:**

Baker, S.F., “NRMO Status Update,” Air Force Air Mobility Modeling and Simulation User’s Conference, Air Force Academy, Colorado Springs, CO, May 1998.

**THESIS DIRECTED:**

Damm, E., “A Comparison of the Force Deployment Estimator (FDE) and Navel Postgraduate School/RAND Mobility Optimizer (NRMO) as Tools for Mobility Analysis,” Master’s Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Mobility, Air Mobility, Optimization



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### GENERALIZED NETWORK ENLISTED COMPONENT OF THE ACTIVE ARMY STRENGTH FORECASTER (A2SF)

**Richard E. Rosenthal, Professor**

**Laura M. Williams, Research Assistant Professor**

**Department of Operations Research**

**Sponsor: Office of the Deputy Chief of Staff, Personnel (ODCSPER), U.S. Army**

**OBJECTIVE:** To research, design, and implement a prototype generalized network model for the enlisted component of the Active Army Strength Forecaster (A2SF). The purpose of the model is to maintain the Army's enlisted force as closely as possible to prescribed levels.

**SUMMARY:** Two models have been designed and implemented: (1) a model with both the grade and specialty detail and (2) a model with the grade detail, but aggregated with respect to specialty, called the Enlisted-Grade (EG) model. The EG model was found to be easier to solve than the original grade and specialty detail model, and was also found to be sufficient to meet the needs of the client. Preliminary verification efforts have begun in preparation for delivery and integration with the A2SF system.

#### CONFERENCE PRESENTATION:

Williams, L., "Generalized Network Enlisted Forecasting Model," British-American Army Forecasting Exchange Conference, West Point, NY, May 1998.

**DoD KEY TECHNOLOGY AREA:** Manpower, Personnel, and Training

**KEYWORDS:** Manpower, Optimization

### METHODOLOGY RESEARCH IN WARGAMING/ANALYSIS

**Richard E. Rosenthal, Professor**

**Laura M. Williams, Research Assistant Professor**

**Lt Col Kirk A. Yost, USAF, Ph.D. Student**

**Department of Operations Research**

**Sponsor: Joint Chiefs of Staff (J-8)**

**OBJECTIVE:** To provide models and analysis which enhance the Capabilities-Based Munitions Requirement (CMBR) process developed by the Under Secretary of Defense for Acquisition and Technology as well as the analysis of force projection and force structure options.

**SUMMARY:** Studies were conducted in two areas: (1) A multi-objective optimization model was developed that attempts to find an optimal allocation of munitions to threats with limited overlap among the services. The allocation was based on three objectives: minimize friendly casualties, maximize enemy casualties and maximize adherence to the guidance delineating proper division of labor among the services. (2) The Naval Postgraduate School/RAND Mobility Optimizer (NRMO) model was upgraded by adding a sealift component. A comparative analysis of the resulting model (NRMOAS) and the model currently used for force deployment modeling (FDE) was performed.

#### CONFERENCE PRESENTATION:

Byrne, P.C., Rosenthal, R.E., and Widdowson, B.L., "A Joint Service Optimization of the Phased Threat Distribution," Military Operations Research Society Symposium, Monterey, CA, June 1998.

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### THESES DIRECTED:

Widdowson, B.L., "A Joint Service Optimization of the Phased Threat Distribution," Master's Thesis, Naval Postgraduate School, March 1998.

Damm, E.M., "A Comparison of the Force Deployment Estimator (FDE) and Naval Postgraduate School/RAND Mobility Optimizer (NRMO) as Tools for Mobility Analysis," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Phased Threat Distribution, Multiple Objectives, Goal Programming, Optimization, Mobility, Air Mobility, Sea Mobility, Force Deployment, Force Projection

### READINESS ASSESSMENT

**David A. Schrady, Distinguished Professor**

**Department of Operations Research**

**Sponsor: Deputy Undersecretary of Defense (Readiness)**

**OBJECTIVE:** The objective was to structure measures of military readiness which allow broad discussion of the subject within the military, with the Congress, and with the public at large.

**SUMMARY:** Though readiness is a commonly used concept, it lacks formal specification and is understood to mean different things to different persons. This state of affairs complicates discussion of readiness and decisions about the level of readiness which should be funded and maintained. The U.S. economy was seen as something which similarly is of broad interest but not formally specified. It was noted that the government established a number of indicators or indices in order to aid discussion and policy making with respect to the economy and that individuals, corporations, and government policy makers find the baseline and trend information in these indicators and indices useful. Readiness indicators were proposed, motivated by the analogy with economic indicators and indices.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Military Readiness, Joint Readiness, Readiness Assessment

### TACTICAL LOGISTICS SUPPORT SYSTEM AND SEA-BASED LOGISTICS

**David A. Schrady, Distinguished Professor**

**Department of Operations Research**

**Sponsor: Naval Sea Systems Command**

**OBJECTIVES:** The first objective was to change the Tactical Logistics Support System (TACLOGS) software so that it complies with DII COE standards. The second objective was to begin modeling sea-based logistics support for its eventual inclusion in TACLOGS.

**SUMMARY:** Several minor changes were made in the existing version of TACLOGS, changes suggested by at-sea use of TACLOGS. Additionally the classified database for TACLOGS was updated to reflect changes in standard air wing composition and changes in standard ordnance load lists. The biggest task has been to rewrite the software in JAVA, to create the HCIs with Visual Café, and to incorporate compliance with DII COE 3.1. The new version of TACLOGS will be compatible with the Global Command and Control System-Maritime 3.1 that will become the Navy standard during 1999 and will run on any platform including a PC with Windows NT 4.0 operating system. The rewrite is not finished, but it is

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## PROJECT SUMMARIES

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expected to be finished in time to be included in the SQT2 operational evaluation of GCCS-M 3.1 in the Spring. Work on sea-based logistics modeling has been secondary to the TACLOGS efforts.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Naval Logistics, Sustainability

### SEA-BASED LOGISTICS

**David A. Schrady, Distinguished Professor**

**Department of Operations Research**

**Sponsor: Naval Postgraduate School-Institute for Joint Warfare Analysis**

**OBJECTIVE:** Quantitative analysis of the operational aspects of the concept of sea-based logistics (SBL) including characterization of the range of types and sizes of forces to be supported by SBL, estimation of the sustainment requirements of such forces, and determination of the feasibility of SBL sustainment for the forces postulated.

**SUMMARY:** Five representative missions were developed for a Marine Expeditionary Unit embarked in an amphibious readiness group of three amphibious warfare ships that would be called upon to provide their sea-based logistics support. For each mission, sustainment requirements were developed from planning factors in the MAGTF Data Library. Under the assumption that force deployment would involve surface and vertical lift and that resupply would be by vertical lift only, the number of aircraft sorties required daily to sustain the force involved in each mission was calculated. Required combat support sorties were compared to the total number of sorties available. An observation drawn is that SBL may require most of the sorties of aircraft which up to now have been considered to have exclusively tactical roles.

### THESIS DIRECTED:

Hagan, Robert M., "Modeling Sea-Based Sustainment of Marine Expeditionary Unit (Special Operations Capable) (MEU(SOC) Operations Ashore," Master's Thesis, Naval Postgraduate School, September 1998.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Sea-Based Logistics, Sustainability, OMFTS, STOM

### TARGET SELECTION IN FORCE-ON-FORCE ATTRITION ALGORITHMS

**James G. Taylor, Professor**

**Department of Operations Research**

**Sponsor: U.S. Army Concepts Analysis Agency**

**OBJECTIVE:** To investigate models for target selection for the attrition-calibration (ATCAL) approach for assessing aggregated force-on-force attrition of large ground-combat units in campaigns for the purposes of joint-warfare, campaign analysis.

**SUMMARY:** Documentation of last year's work was completed. Last year, a general framework for viewing aggregated-force attrition models/algorithms was developed and used as a point of departure for developing methodology for the theoretical comparison/evaluation of existing attrition methodologies. Three major methodologies for aggregated ground-combat attrition were identified and a comparative evaluation of them made. The theoretical basis of the ATCAL method was investigated (e.g., the underlying Lanchester-type equations were developed). Computational methods for determining losses of large-scale ground-combat forces were investigated, as well as the context (including supporting calculations and determinations) for such assessments.

## PROJECT SUMMARIES

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### CONFERENCE PRESENTATION:

Taylor, J.G., Mansager, B.K., and Brown, R., "Redesign of ATCAL Attrition Algorithm for Military OR Problems in the Twenty-First Century," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** Combat Models, Lanchester Attrition-Rate Coefficient, Target Selection

### RESEARCH ON AGGREGATED COMBAT MODELS II

**James G. Taylor, Professor**

**Department of Operations Research**

**Sponsor: U.S. Army Concepts Analysis Agency**

**OBJECTIVE:** To improve quantitative methodology for assisting in the selection of aggregated-force combat models and submodels, particularly for the attrition process. Also, to improve attrition methodologies for such models.

**SUMMARY:** This work was the continuation of last year's research on target selection for the attrition-calibration (ATCAL) methodology used extensively by CAA in their large-scale combat models. Research focused on determining the theoretical basis of ATCAL (i.e. underlying conceptual and mathematical models and solution methodology for the mathematical equations) and identifying how to improve it. Based on development of general hierarchy-of-models methodology, the ATCAL algorithms (both replay model and estimation of parameter values from high-resolution-combat-simulation output) were completely re-engineered and suggestions for short-term improvement (of the existing algorithms) developed. Also, a critique of the proposed JWARS ground-combat attrition methodology was written. The director of CAA will be briefed on these accomplishments in early 1999. The critique of the proposed JWARS ground-combat attrition methodology was briefed to senior OSD PA&E managers and the Scientific Advisor of The Joint Staff (October 1998) and AMSO's Standards Coordinating Committee (SCC) for Attrition (December 1998). As a result of this, the investigator was made a member of the Army Modeling and Simulation Office (AMSO) SCC for attrition. Also, improvements that overcome a fundamental flaw that had gone undetected for about 25 years were made in so-called Bonder-Farrell attrition methodology. A very serious flaw (that had gone undetected for about fifteen years) in how ATCAL determines its target-priority list for so-called Phase II calculations was discovered.

### CONFERENCE PRESENTATIONS:

Taylor, J.G., "Initial Theoretical Evaluation of JWARS Ground-Combat Attrition Model," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Single-System Kill Rates by the Bonder-Farrell Approach," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Markov-Chain Models of Target Availability," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Overview of Aggregated-Force Attrition Methods," INFORMS Cincinnati Spring 1999 Meeting, Cincinnati, OH, 29 April-6 May 6, 1999, to be given.

Clark, G.M., Buss, A.H., and Taylor, J.G., "Hierarchy-of-Models Approach for Determining Lanchester Attrition-Rate Coefficients," INFORMS Cincinnati Spring 1999 Meeting, Cincinnati, OH, 29 April-6 May 1999, to be given.

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## PROJECT SUMMARIES

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### THESIS DIRECTED:

Shenk, Michael L. "Development of a Test Mechanism for Analyzing Force Attrition Methodologies within Aggregated Combat Simulations," Master's Thesis, Naval Postgraduate School, June 1998.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** Ground-Force-on-Force Attrition, Attrition-Calibration (ATCAL) Method, Joint Warfare System (JWARS)

### SUPPORT AND REVIEW OF THE MODELING OF GROUND COMBAT IN INTEGRATED THEATER ENGAGEMENT MODEL (ITEM)

**James G. Taylor, Professor**

**Department of Operations Research**

**Sponsor: Joint Training, Analysis, and Simulation Center (JTASC)**

**OBJECTIVE:** To provide necessary background and inputs for specific topics/methodologies (concerning the representation of ground combat) of interest to the Joint Training, Simulation and Analysis Center (JTASC) to support its use/development of the Integrated Theater Engagement Model (ITEM).

**SUMMARY:** This work continued a project started last year. In the previous year, the theoretical basis of the attrition-calibration (ATCAL) method for assessing aggregated force-on-force attrition was investigated (e.g. the underlying Lanchester-type equations were developed for the case of point-fire attrition, the limiting behavior of these equations was investigated). An initial computational investigation revealed that substantial errors might be involved in the use of an exponential-decay assumption in the ATCAL algorithm. Consequently, major changes in the computational methods (e.g., numerical integration and maximum likelihood estimation of model parameters) for ATCAL were proposed and some details worked out. This year further details were worked out and documented.

### PUBLICATION:

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, with Applications to Algorithm Development," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

### CONFERENCE PRESENTATIONS:

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, With Applications to Algorithm Development," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Suggested Changes in the Integrated Theater Engagement Model (ITEM)," ITEM User's Group Meeting, San Diego, CA, 15 July 1998.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation

**KEYWORDS:** Ground-Force-on-Force Attrition, Att<sup>r</sup>ition-Calibration (ATCAL) Method, Joint-Warfare Campaign Models

### NEW METHODOLOGY FOR AGGREGATED COMBAT MODELS

**James G. Taylor, Professor**

**Department of Operations Research**

**Sponsor: U.S. Marine Corps Combat Development Command**

**OBJECTIVE:** To evaluate the adequacy of existing combat-modeling methodologies (especially for attrition) and models (especially JWARS) for current and future USMC Combat Development Command analysis needs.

**SUMMARY:** Work was barely initiated on development of a hierarchy-of-models approach to modeling combat attrition in situations of interest to the sponsor, when the investigator became concerned about the proposed JWARS ground-combat attrition methodology. A critique was made (PowerPoint presentation) and reported to the sponsor. This critique was briefed to senior OSD PA&E managers and the Scientific Advisor of The Joint Staff (October 1998) and later AMSO's Standards Coordinating Committee (SCC) for Attrition (December 1998). As a result of this, the investigator was made a member of the Army Modeling and Simulation Office (AMSO) SCC for attrition. This has also led to the investigator developing (an alternate/risk-mitigating) attrition methodology for WARSIM, the Army's part of JSIMS (and an area of interest to the USMC).

#### CONFERENCE PRESENTATION:

Taylor, J.G., "Overview and Directions for Aggregated-Force Combat Models," 67th Military Operations Research Society Symposium, West Point, NY, June 22-24, 1999 (to be given).

#### OTHER:

Project presentation given to senior pentagon officials (Jim Johnson, Director OSD PA&E Ground Forces, Eric Colter, OSD PA&E Force Projection, Dr. Kevin Saeger, Director Joint Data System OSD PA&E, and Vince Roeske, Scientific Advisor The Joint Staff): Taylor, J.G., "Initial Theoretical Evaluation of JWARS Ground-Combat Attrition Model," Project Presentation for MCCDC, Quantico, VA, October 1998.

Taylor, J.G., "Single-System Kill Rates for the Bonder-Farrell Approach," Project Presentation for MCCDC, Quantico, VA, October 1998.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Ground-Force-on-Force Attrition, Att<sup>r</sup>ition-Calibration (ATCAL) Method, Joint Warfare System (JWARS)

### SUPPORT OF COMBAT MODELING

**James G. Taylor, Professor**

**Department of Operations Research**

**Sponsor: Simulation and Analysis Center, Office of the Secretary of Defense**

**OBJECTIVE:** To provide necessary background and inputs for specific topics/methodologies of interest to the Simulation and Analysis Center (SAC) to support its use/development of computer-based combat models.



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**SUMMARY:** This was the completion of a project initiated in the previous year. Last year, the theoretical basis of the attrition-calibration (ATCAL) method for assessing aggregated force-on-force attrition was investigated (e.g., the underlying Lanchester-type equations were developed for the case of point-fire attrition). The goodness of the approximation upon which the attrition algorithm is based was partially investigated. The basic ATCAL assessment equations (upon which the ATCAL attrition algorithm for the case of point-fire attrition is based) were derived from these underlying Lanchester-type equations. The limiting behavior of these equations was investigated. This year the mathematical behavior of the underlying Lanchester-type differential equations for ATCAL was investigated.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Joint-Warfare Models, Aggregated-Force Attrition, Lanchester-Type Models

### NPS SUPPORT FOR UAV CONOPS DEVELOPMENT

**Alan Washburn, Professor**

**Department of Operations Research**

**Sponsor: Chief of Naval Operations (N88)**

**OBJECTIVE:** Unmanned aerial vehicles will play an important role in future naval operations, but operational concepts need to be worked out. This research examines one of the many tasks that UAVs might undertake: Surface Search and Surveillance (SSC).

**SUMMARY:** UAVs will undertake tasks that are dangerous, dirty, and/or dull. SSC is one of the dull kind. A battle group must keep track of all contacts within several hundred miles of PIM (the group center). Contacts are easy to detect by active means, but must still be overflown to establish identity and intent. A vertical takeoff and landing (VTOL) UAV based on a helicopter platform can make a significant contribution to accomplishing this SSC mission. The UAV's role will be to make repeated flights, each of which visits one or more targets of interest. The utility of the UAV will depend on its sensors, its speed and endurance, its command and control system, its method of prioritizing targets, and on unrelated parameters such as target density and battle group speed. The Monte Carlo simulation UAV\_SSC developed in this project is designed to facilitate assessment of UAV utility.

#### **OTHER:**

UAV\_SSC is a Visual Basic simulation of a UAV in the SSC role. It has both graphic and statistical modes, with the latter being the former speeded up by omitting the pictures. It simulates a battle group proceeding at a fixed speed and direction through a sea containing targets proceeding at a different fixed speed and in random directions. Targets entering the battle group's envelope eventually are visited by the UAV, perhaps repeatedly if they are "bad guys." UAV\_SSC is available from the author at washburn@nps.navy.mil.

**DoD KEY TECHNOLOGY AREAS:** Air Vehicles, Modeling and Simulation

**KEYWORDS:** VTOL, UAV

### FAMILIARIZATION OF NPS FACULTY WITH SUBMARINE SECURITY PROBLEMS

**Alan Washburn, Professor**

**James Eagle, Professor**

**Department of Operations Research**

**Sponsor: Applied Physics Laboratory, Johns Hopkins University**

**OBJECTIVE:** To allow Professors Washburn and Eagle to visit APL/JHU and familiarize themselves with the submarine security problems being pursued.

## PROJECT SUMMARIES

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**SUMMARY:** Professors Washburn and Eagle visited APL/JHU several times and discussed several submarine security problems.

**DoD KEY TECHNOLOGY AREA:** Undersea Warfare

**KEYWORDS:** Submarine Security

### **LARGE-SCALE MIXED INTEGER PROGRAMMING**

**R. Kevin Wood, Associate Professor**

**Department of Operations Research**

**Sponsor: Joint Warfare Analysis Center**

**OBJECTIVE:** This continuing research program seeks to develop theory and algorithms for exploiting special structure in large-scale optimization models used by JWAC.

**DoD KEY TECHNOLOGY AREA:** Other (Design Automation)

**KEYWORDS:** Large-Scale Mixed Integer Programming